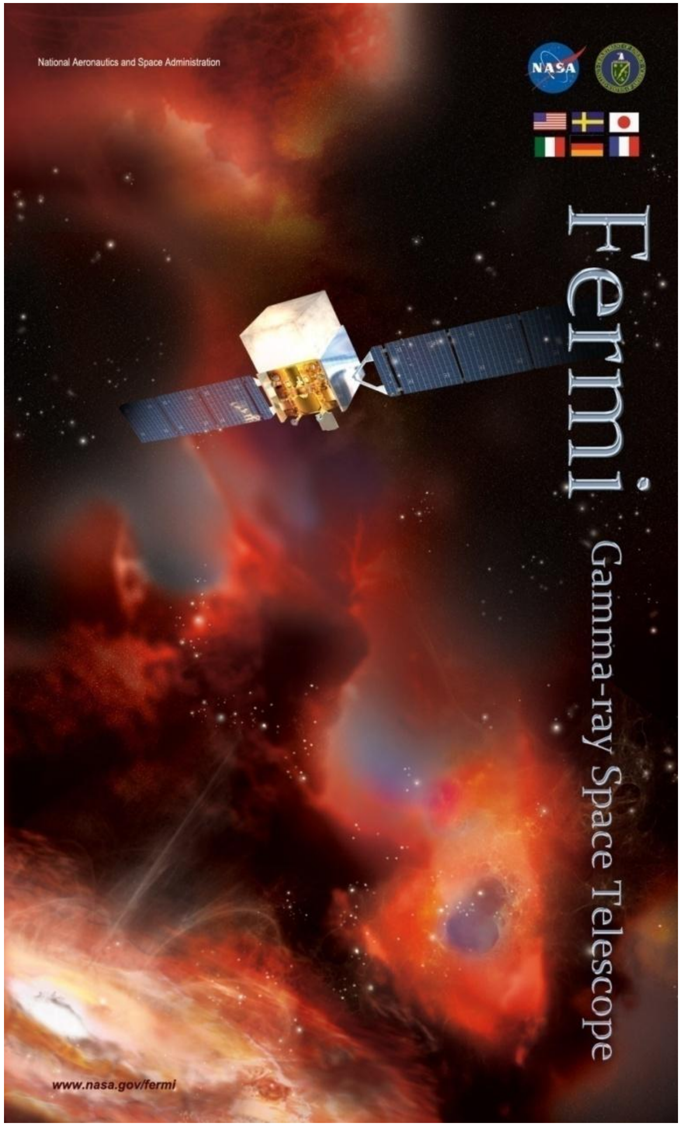

Four Years of Fermi LAT observations of Narrow-Line Seyfert 1 galaxies

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and

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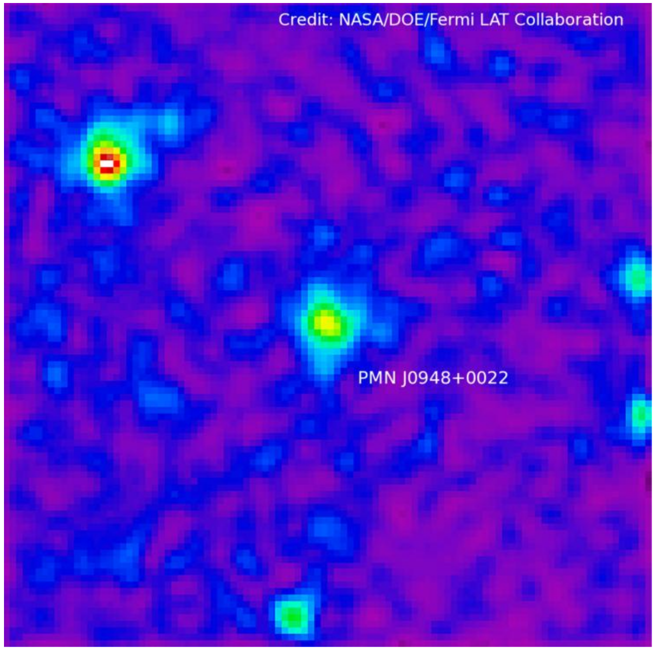
on behalf of the Fermi LAT Collaboration

Gamma-ray emitting NLS1s

- Before the *Fermi* satellite, γ-ray emitting AGNs were only blazars and radio galaxies

- *Fermi*-LAT first 2 years (1FGL and 2FGL) confirmed that the known extragalactic γ-ray sky is dominated by those two classes but...

...first detection of a γ-ray emitting Narrow-line Seyfert 1 in 2008: PMN J0948+0022 and after that other 4 NLS1s were detected in gamma rays

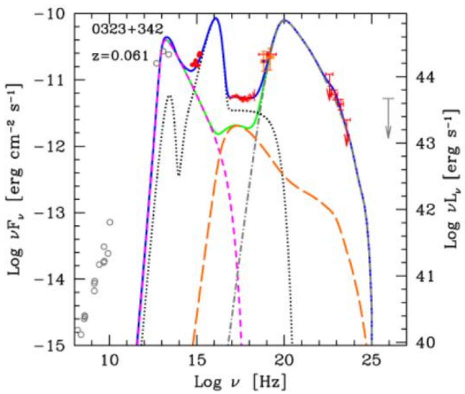


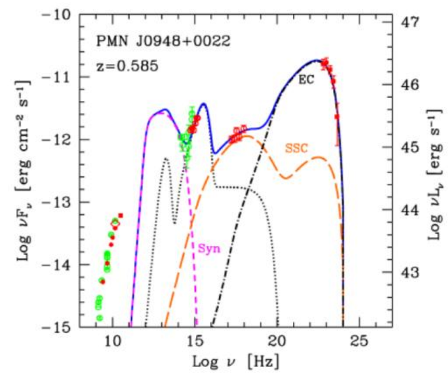
Confirmation of the presence of relativistic jets also in NLS1s

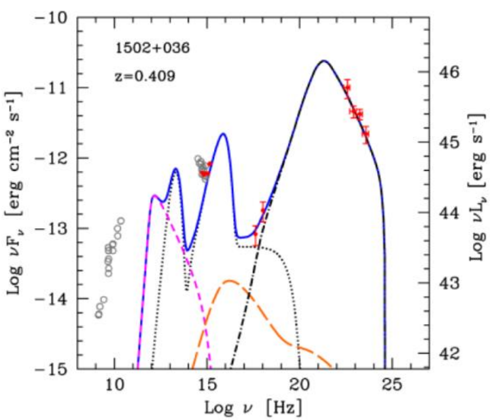
NLS1s are usually hosted in **spiral galaxies**, the presence of a relativistic jet in these objects seems to be contrary to the paradigm that the formation of relativistic jets could happen only in elliptical galaxies (e.g. Boettcher and Dermer 2002, Marscher 2009).

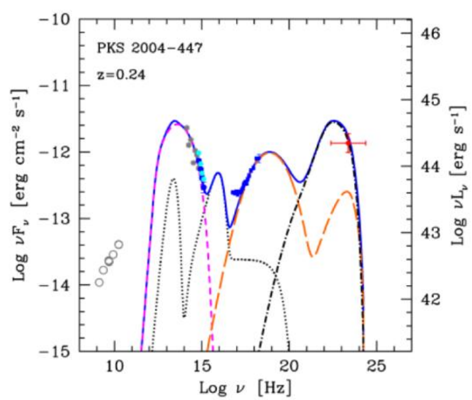
Narrow-Line Seyfert 1s and Fermi-LAT

4 Narrow-Line Seyfert 1s in the 1FGL catalog









1H 0323+342

PMN J0948+0022

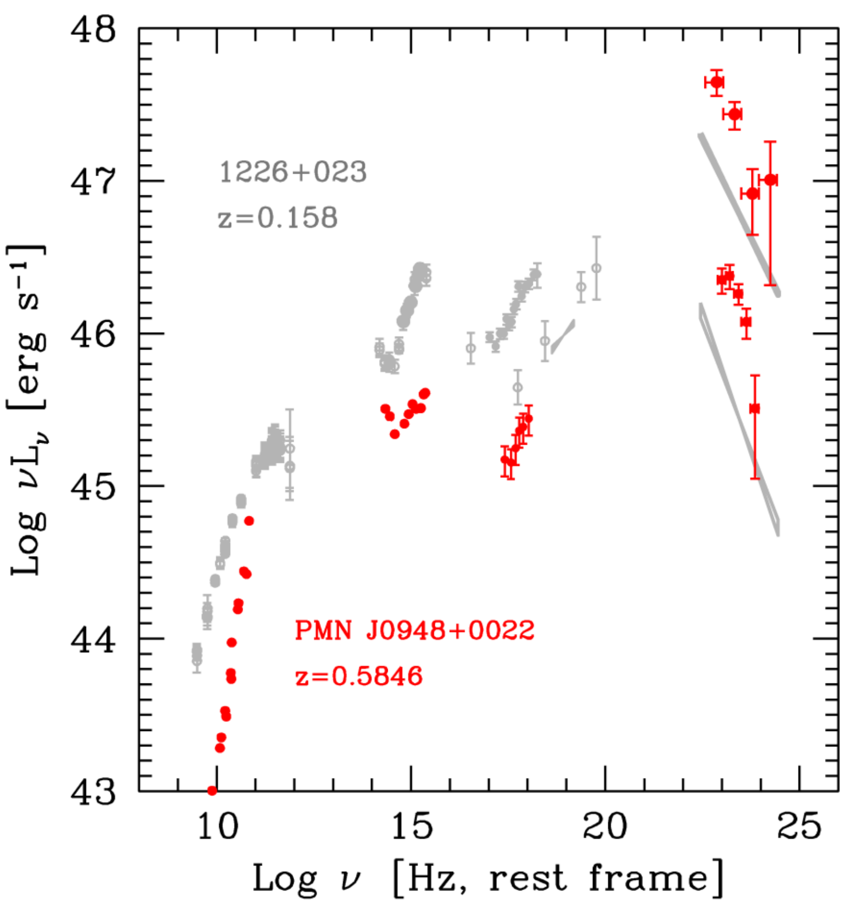
PKS 1502+036

PKS 2004-447

Abdo+09

No new NLS1 in the 2FGL catalog

FSRQs vs RL-NLS1s

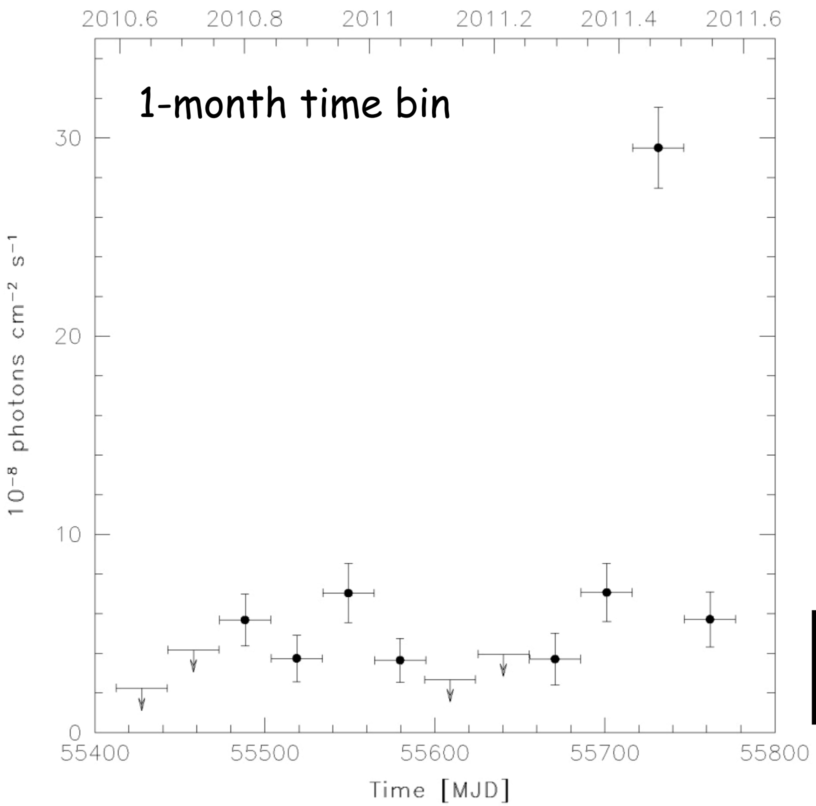


Foschini+11

- The comparison of the SED of PMN J0948+0022 in July 2010 with the SED of a typical blazar with a strong accretion disk (3C 273) shows that the Compton dominance is more extreme in the NLS1s

- The disagreement of the two SEDs can be accounted by the differences in mass of the central BH and Doppler factor of the two jets

SBS 0846+513: a new gamma-ray NLS1

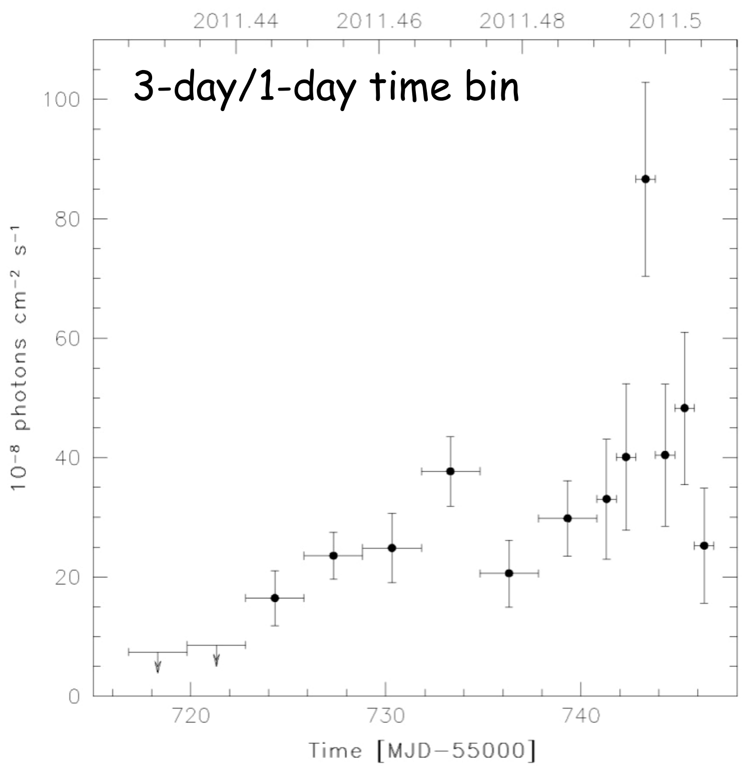


SBS 0846+513 was not detected in gamma rays with TS > 25 during the first 2 years of Fermi operation. UL ~8.5e-9 ph cm^{-2} s^{-1}

D'Ammando, Orienti, Finke , et al. MNRAS 426, 317, 2012

SBS 0846+513 clearly detected in gamma rays with TS = 653 (~25σ) **during the third year of Fermi operation.** Flux $_{E>100\ MeV}$ = (6.7±0.5)e-8 ph cm^{-2} s^{-1} and Γ = 2.23±0.05

A gamma-ray flare from SBS 0846+513

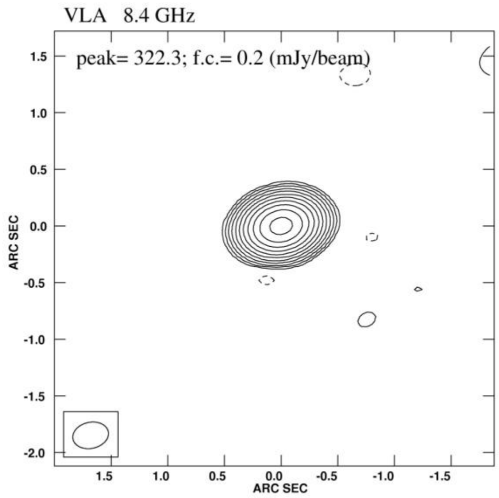


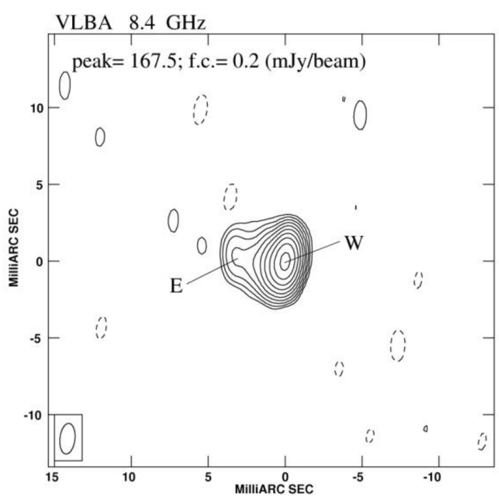
During the month of high activity there was spectral evolution in gamma rays, as already observed in other FSRQs

The gamma-ray peak with daily timescale on 30 June 2011 is (87±16)e-8 ph cm^{-2} s^{-1}, corresponding to an isotropic luminosity of ***~10^{48} erg s^{-1}, comparable to that of the bright FSRQs.***

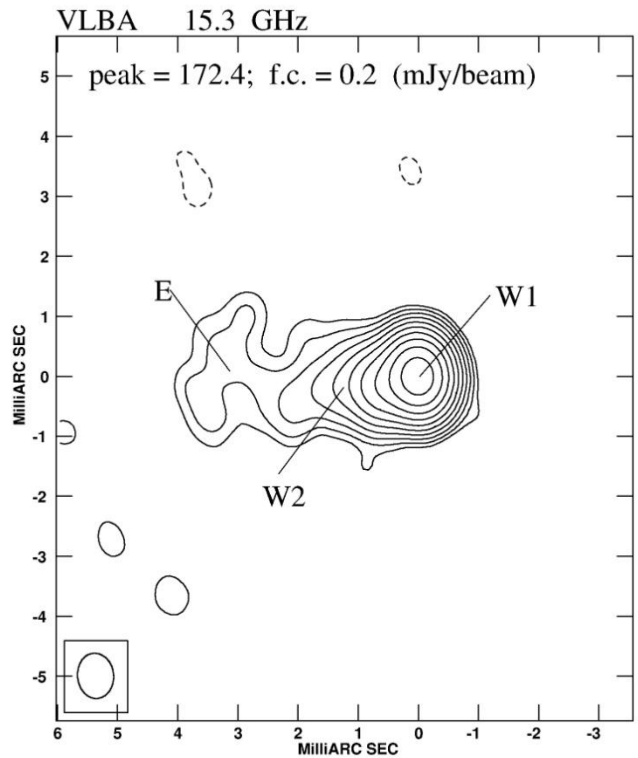
D'Ammando, Orienti, Finke , et al. 2012

The radio view of SBS 0846+513



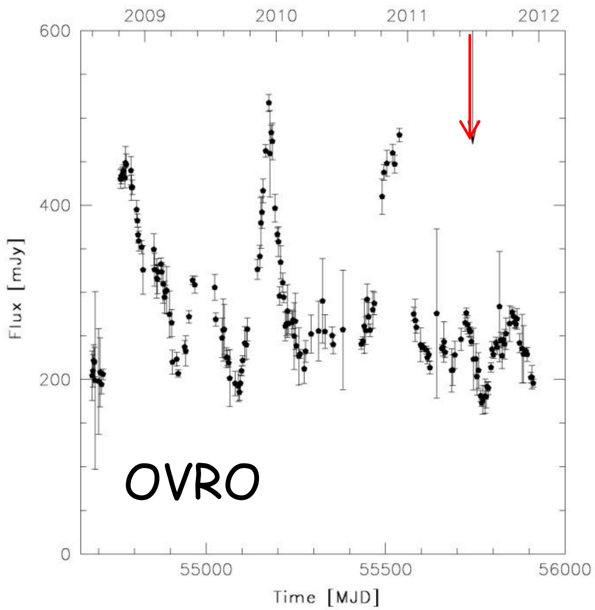


Core-jet structure on parsec scale.
Unresolved with the VLA.



D'Ammando, Orienti, Finke , et al. 2012

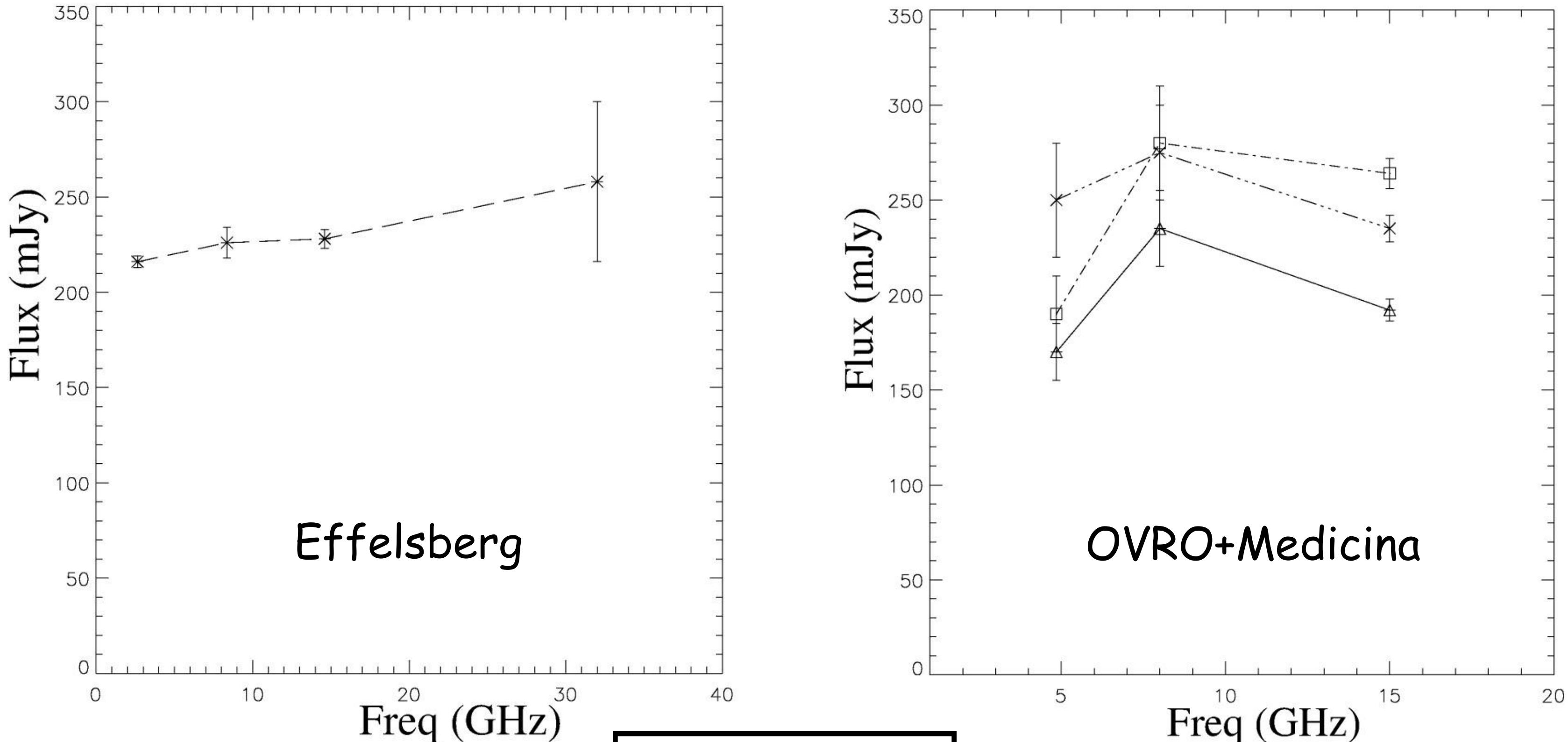
The radio variability of SBS 0846+513



The OVRO light curve showed strong variability at 15 GHz, but not so high during the peak of the gamma-ray activity

From the model-fitting of 4-epoch MOJAVE data in 2010-2012 we found that W1 and W2 are separating with an **apparent velocity of (10.9+/-1.4)c**. This value suggests the presence of boosting effect as well as in blazars (see D'Ammando, Orienti, Finke 2012, Proc. Gamma2012)

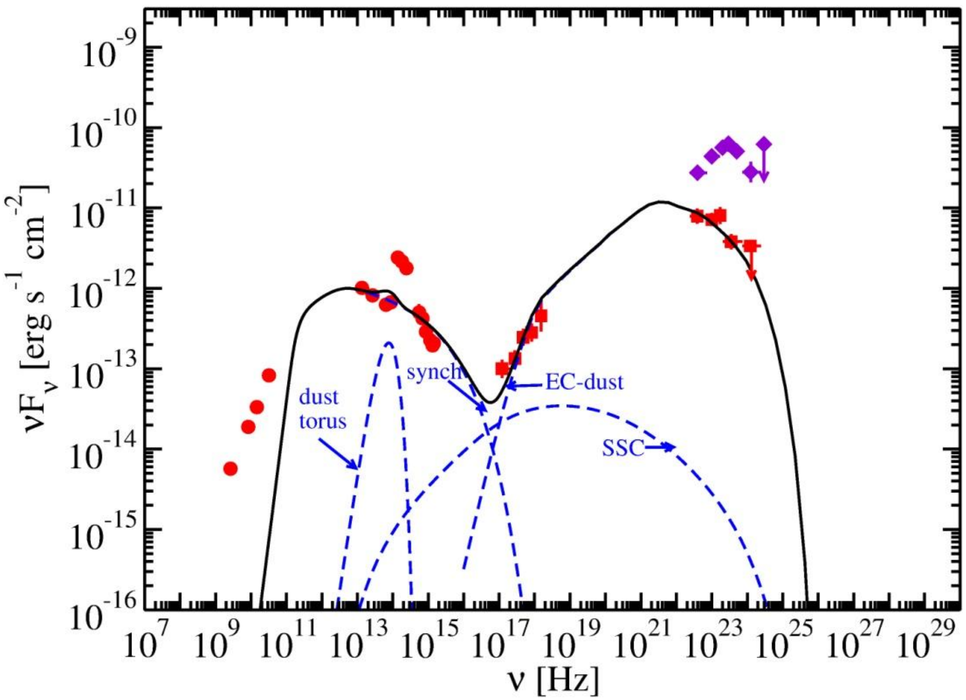
The radio spectra of SBS 0846+513



D'Ammando+2012

A flat radio spectrum was observed on April 2011, before the high gamma-ray activity. After the gamma-ray flare (August-November 2011) also the radio shape changed, a quite typical blazar-like behaviour.

Spectral energy distribution of SBS 0846+513



D'Ammando+2012

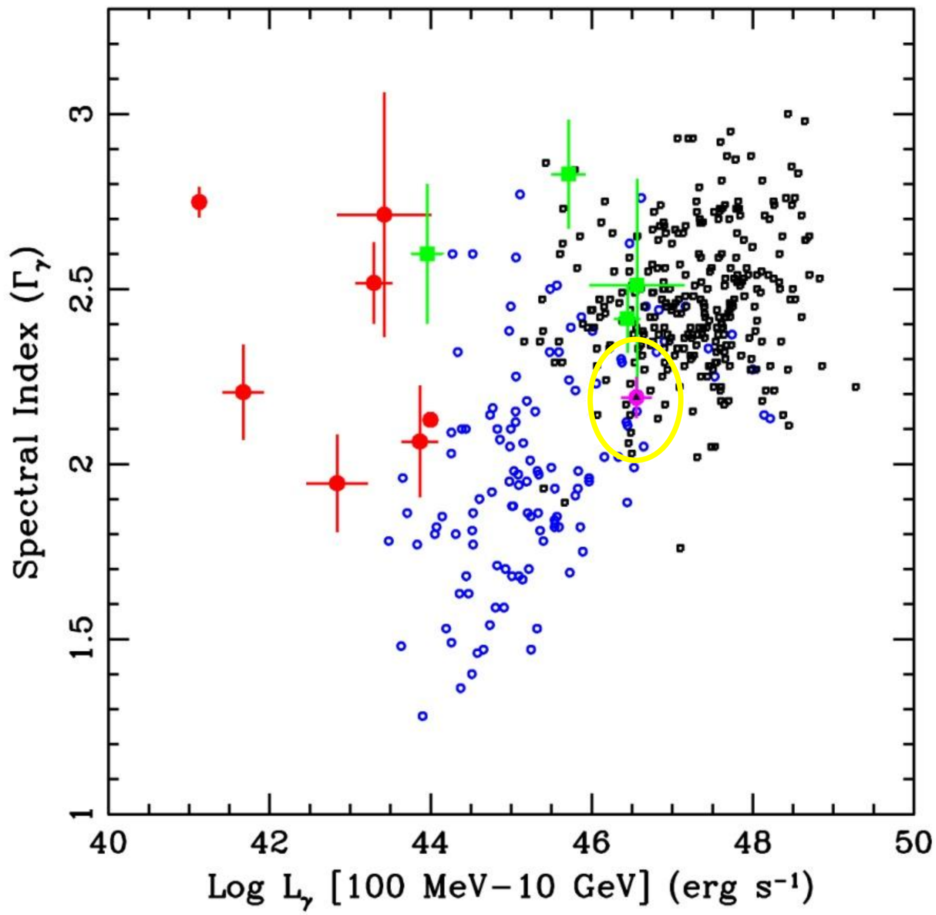
Modeling of the SED of the source in a low state with SSC+EC (dust).

Γ = 15, B = 1 G, P_jet = 1.8x10^{45} erg s^{-1}

Magnetic field and electrons energies are nearly in equipartition.

Compton dominance (~7) and X-ray spectral index consistent with FSRQs

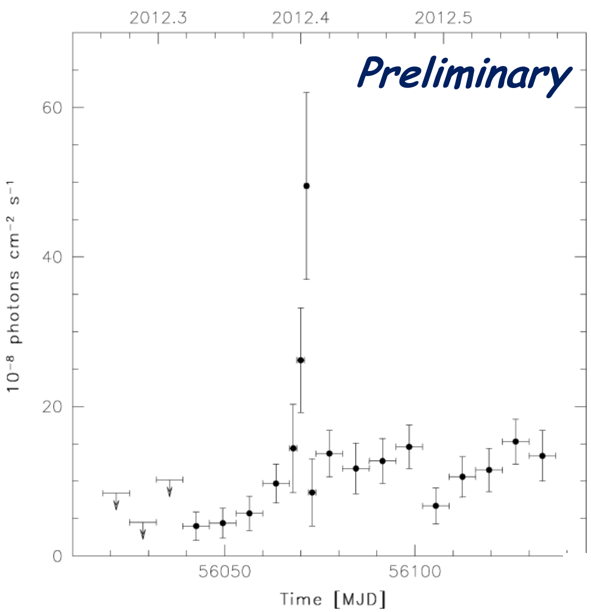
Gamma-ray luminosity and spectrum



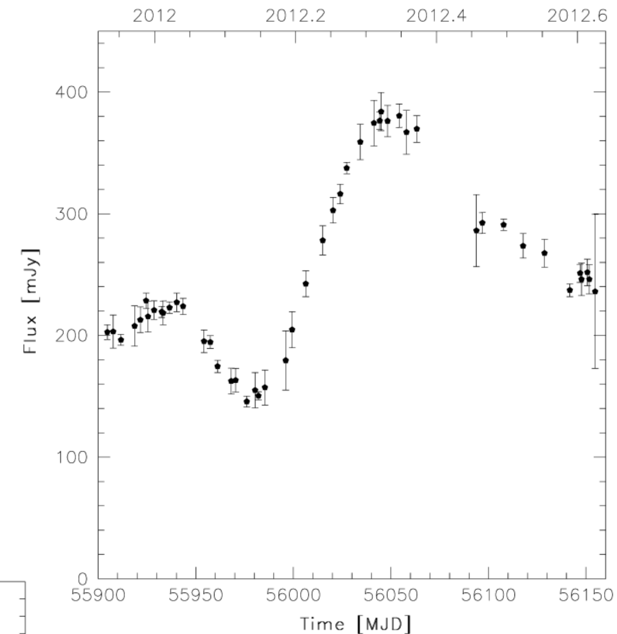
D'Ammando+2012

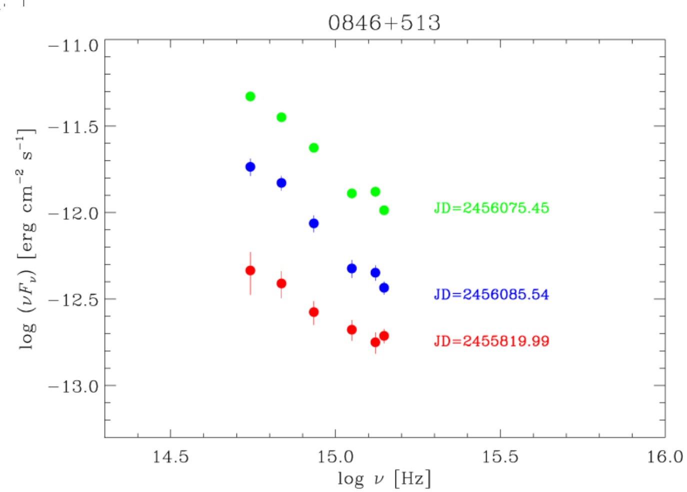
The average isotropic gamma-ray luminosity (0.1-10 GeV) is 3.6×10^{46} erg s^{-1} with $\Gamma = 2.19$. In L_γ-Γ plane SBS 0846+513 lies in the blazar region

A new gamma-ray activity from SBS 0846+513



After some months of quiescent activity SBS 0846+513 has been detected by Fermi-LAT in April-July 2012, with high flux at the end of May.





A hint of the accretion disk emission has been detected by UVOT in May-June 2012

Unlike the 2011 activity, a contemporaneous increase of activity has been observed by OVRO in May 2012 at 15 GHz

D'Ammando et al. in prep.

Concluding Remarks about SBS 0846+513

• The power released by SBS 0846+513 during the flaring activity and the apparent superluminal velocity are strong indications of the presence of a relativistic jet as powerful as those of blazars

• Variability and spectral properties in radio and gamma rays bands indicate blazar-like behaviour

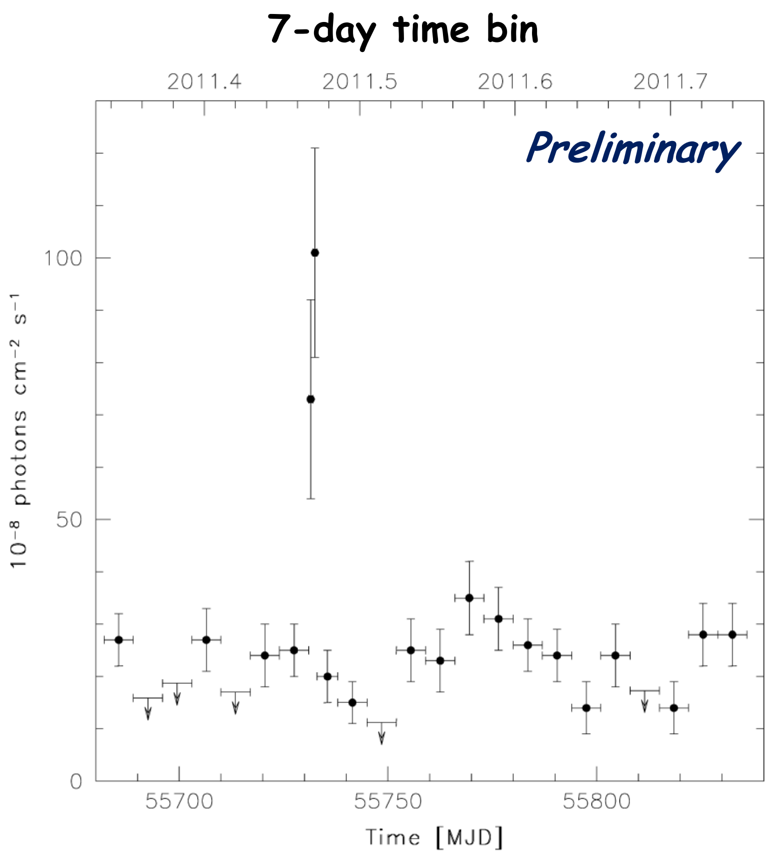
• The black hole mass of SBS 0846+513 was estimated in the range between 8.2×10^6 and 5.2×10^7 solar masses

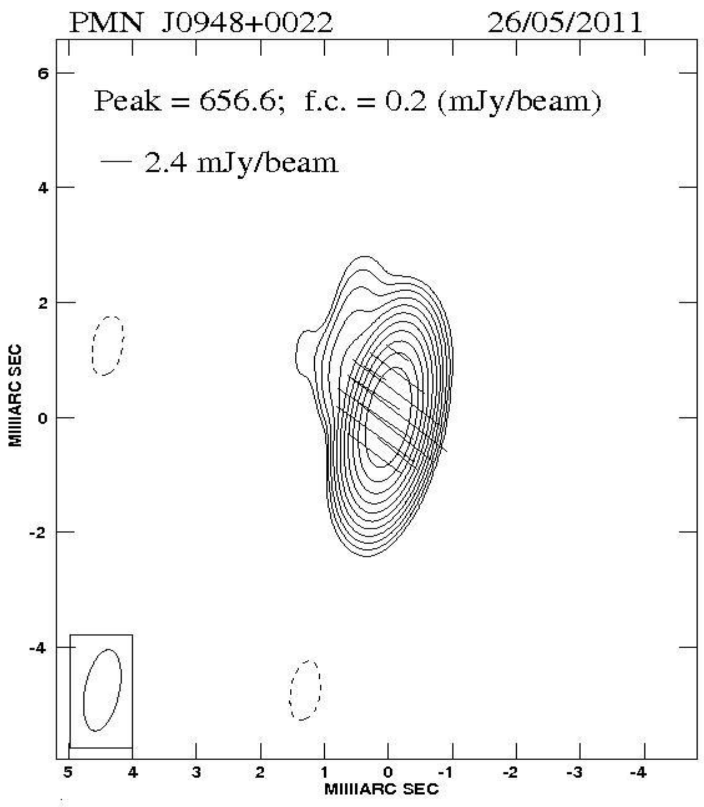
• This source could be a blazar at the low end of the blazar's BH masses (possibly young), indicating that radio-loud AGNs can host relativistic jets as powerful as those of blazars, despite the BH mass

• *The discovery of relativistic jets in a class of AGN usually hosted by spiral galaxies was a great surprise but…*

…BH masses of radio-loud NLS1s are larger than the entire sample of NLS1s. This could be related to prolonged accretion episodes that can spin-up the BH leading to the relativistic jet formation. Only for a small fraction of NLS1s the high accretion lasts sufficiently long to significantly spin-up the BH

A second gamma-ray flare of PMN J0948+0022



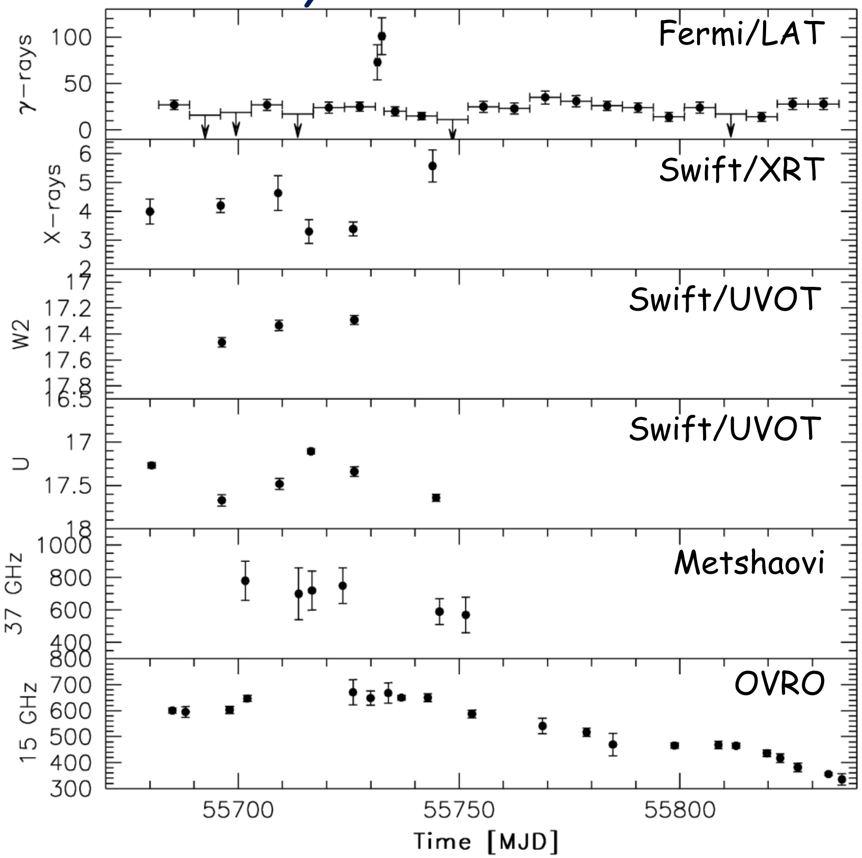


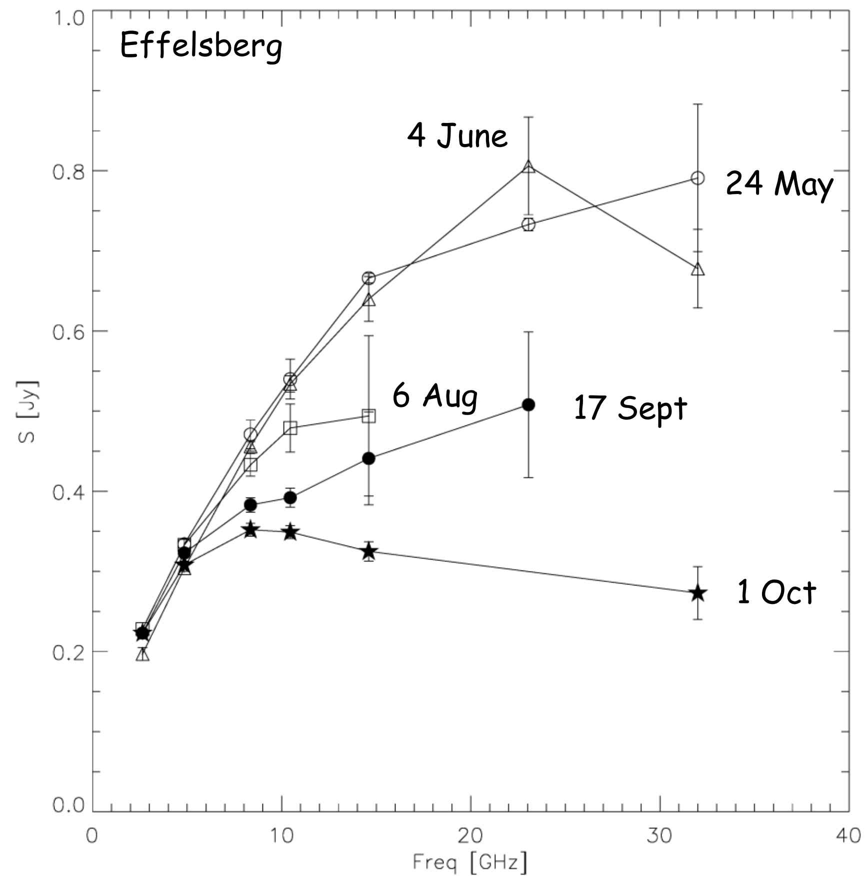
D'Ammando et al. in prep

$L_\gamma \sim 10^{48}$ erg s^{-1} at peak on 20 June 2011, comparable to the July 2010 flare.
A core-jet structure observed on parsec scale.

MWL data of PMN J0948+0022

Preliminary

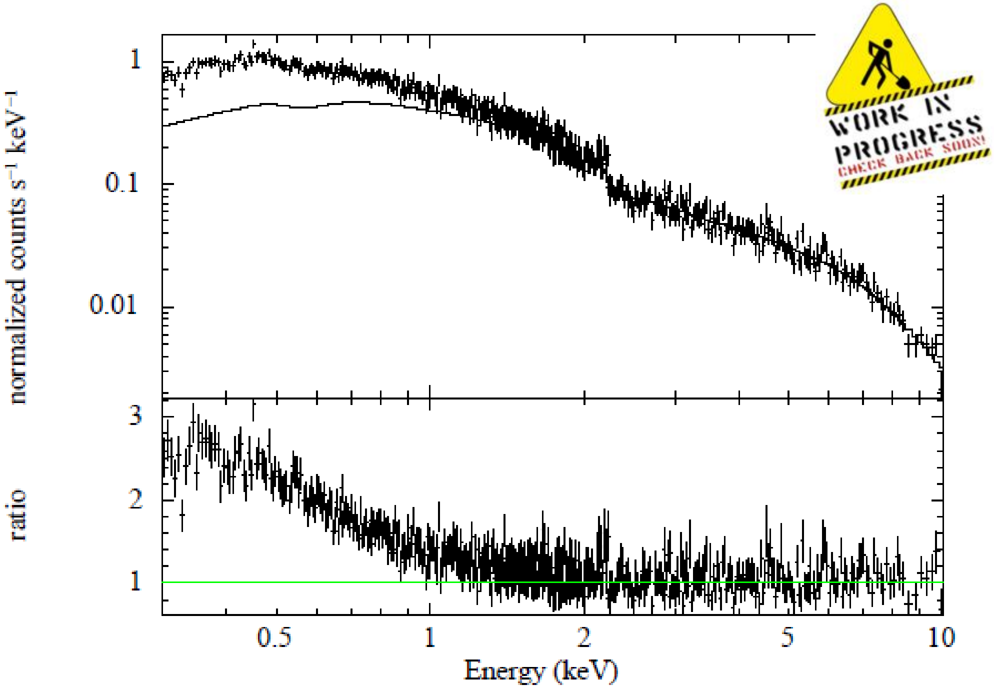




D'Ammando et al. in prep

Radio spectra and fluxes show a high activity of the source still in May 2011 ***before*** the peak of the gamma-ray activity

XMM observation of PMN J0948+0022



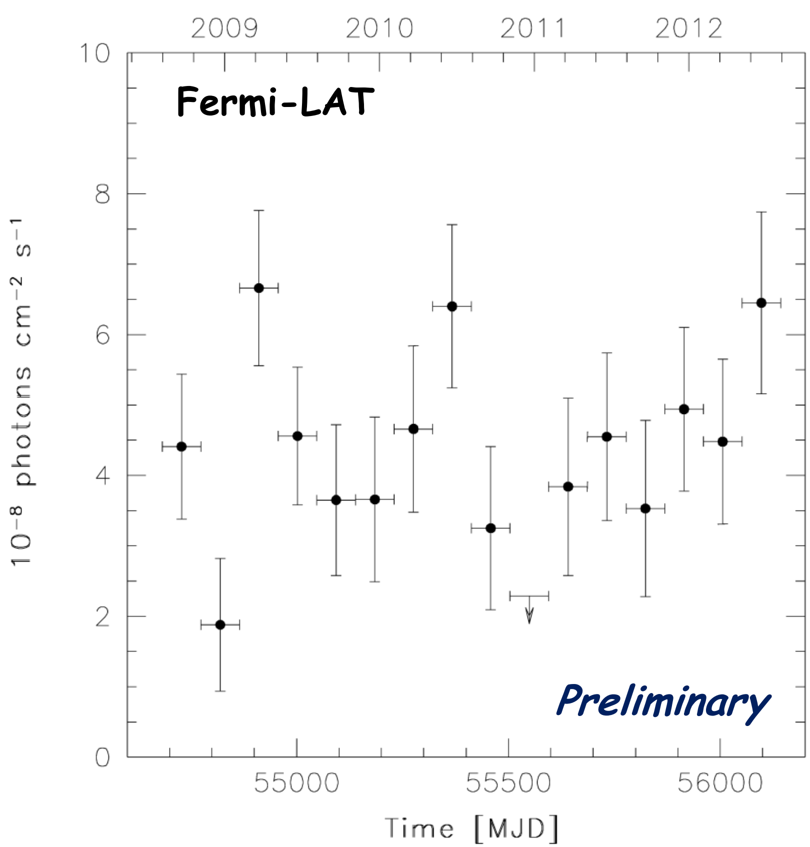
Γ = 1.93 $\pm$ 0.05 in the 0.3-10 keV energy range, χ^2_{red} = 1.91/153

A simple power law in 2-10 keV is a good fit (χ^2_{red} = 0.93/108) Γ = 1.50$\pm$0.05

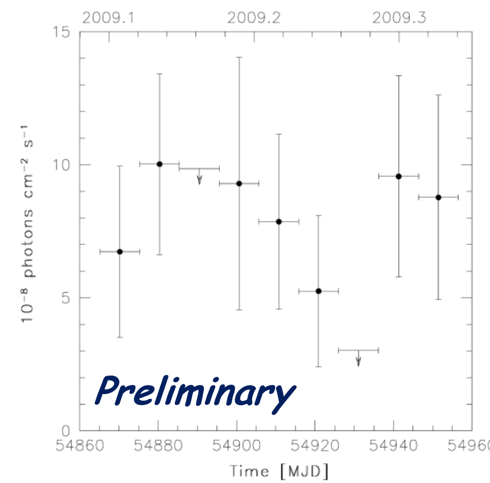
A clear *soft excess* observed, notwithstanding the non-thermal jet emission!

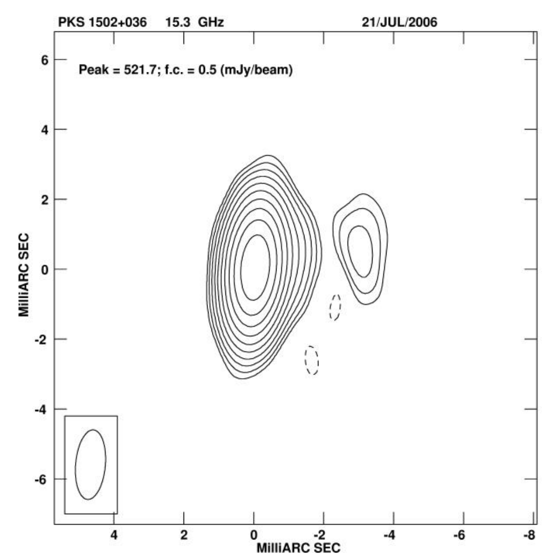
A power law + black body give a good fit (χ^2_{red} = 1.02/151) Γ = 1.60 $\pm$ 0.02, kT = 175 $\pm$ 10 eV.
Expected kTmax for a standard SS accretion disc in PMN J0948+022 is about 17 eV, a factor of 10 lower than the kT obtained by the fit…but in NLS1 we have high accretion rate so high kTmax?

PKS 1502+036



D'Ammando et al. in prep

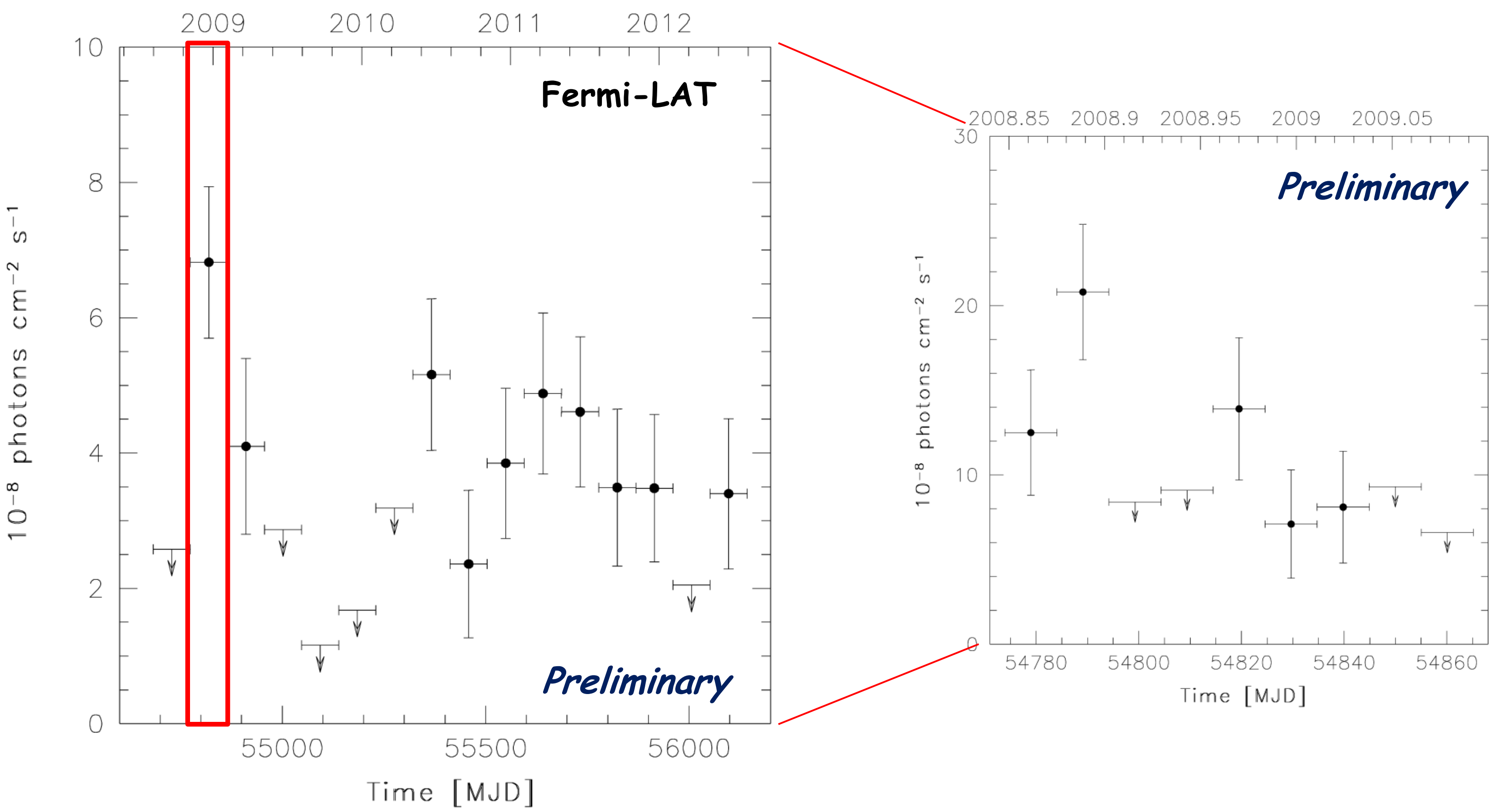




VLBA observtions allowed us to detect a new knot of the jet at about 3 mas from the central region with an apparent superluminal velocity

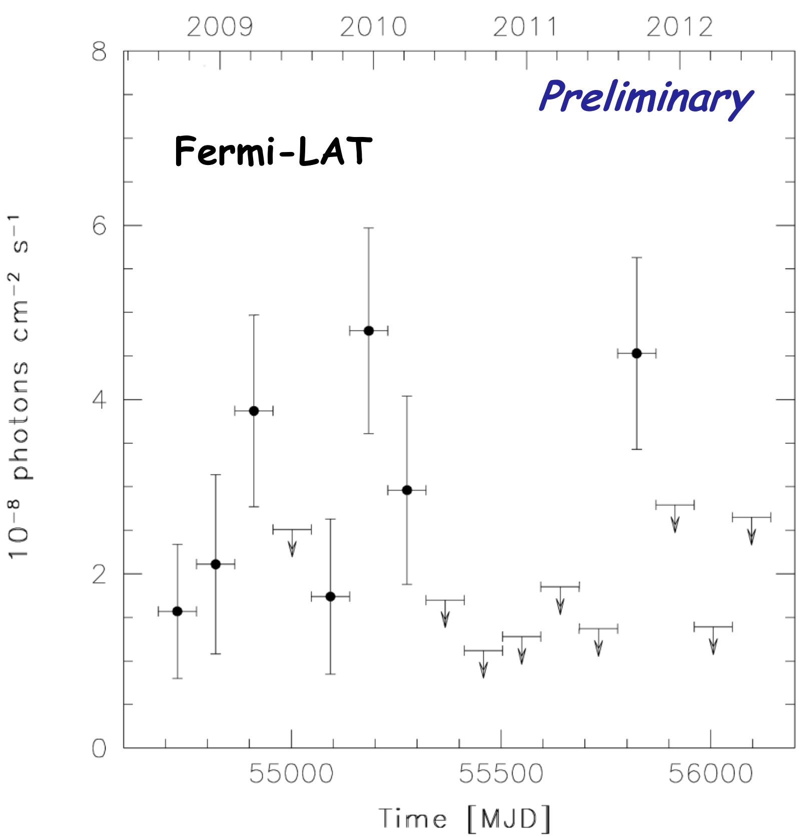
Orienti, D'Ammando, Giroletti 2012

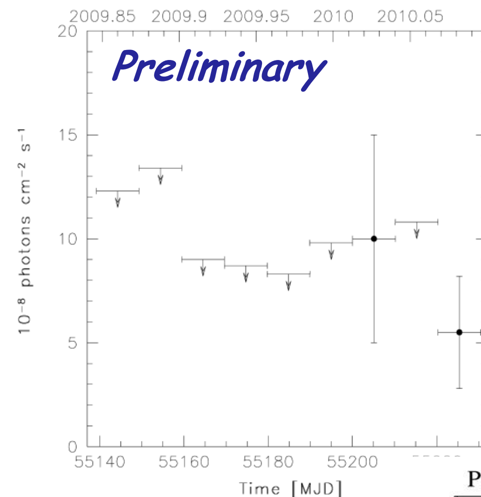
1H 0323+342 – 4 years LAT observations



D'Ammando et al. in prep.

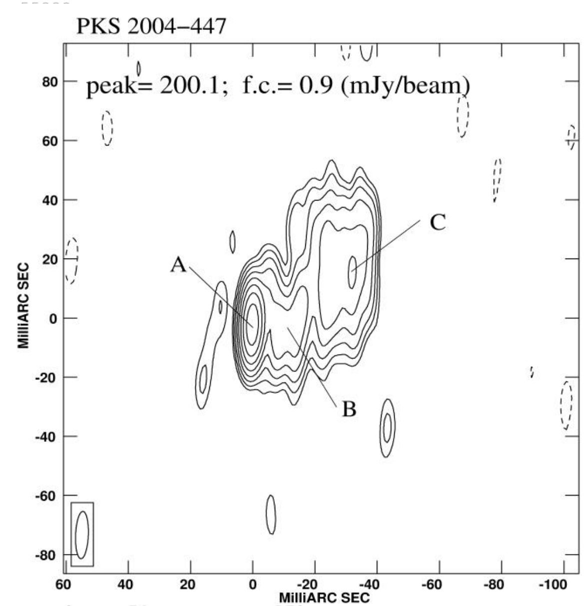
PKS 2004-447: a 'genuine' NLS1 or a CSO?





No significant activity in gamma rays

D'Ammando et al. in prep



Orienti, D'Ammando, Giroletti 2012

The bright and compact component A may be either the core or a very compact hot-spot like those found in a few young radio sources

New gamma-ray NLS1s?

- We are analyzing 4 years of LAT data (2008 August 4 - 2012 August 4) for searching new radio-loud NLS1 in gamma rays on different time scales (4-yr, 1-yr, 1-mont, etc.)

- We started from a list of 39 sources reported in Yuan et al. (2008), Zhou & Wang (2002), Whalen et al. (2006), Komossa et al. (2006) and Oshlack et al. (2001) with a radio-loudness R > 20

- No high-significance (TS > 25) detection of new gamma-ray NLS1s over 4-year period, but a few possible new candidates…

Concluding Remarks II

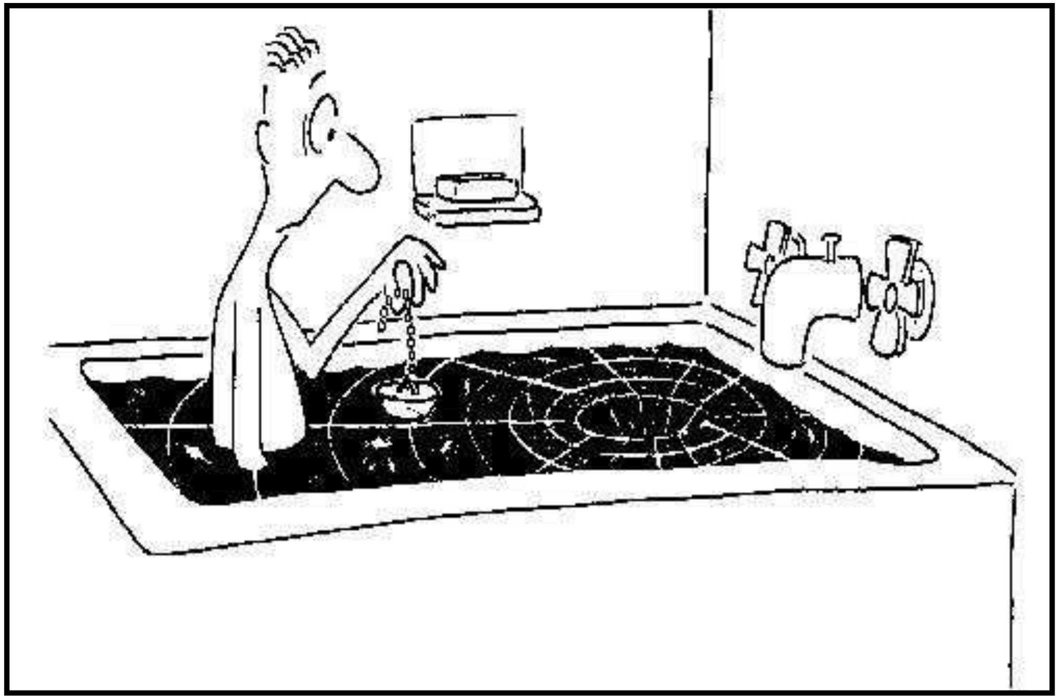
• At least two gamma-ray Narrow-Line Seyfert 1s showed intense gamma-ray flares, thus NLS1 can host relativistic jets as powerful as blazars. Are these two sources peculiar also among the NLS1s?

• Radio and gamma-ray data collected for SBS 0846+513 and PMN J0948+0022 suggest spectral and variability properties similar to blazars, and the modeling of the average SED gives similar results to those of blazars. What are the differences with respect to blazars?

• NLS1s have peculiar optical characteristics with respect to blazars, what is the influence of them for the high-energy emission mechanisms?

• Radio-loud NLS1s have smaller BH masses with respect to blazars, the detection of relativistic jets in some radio-loud NLS1s is in contrast with the current theories of development of relativistic jets?

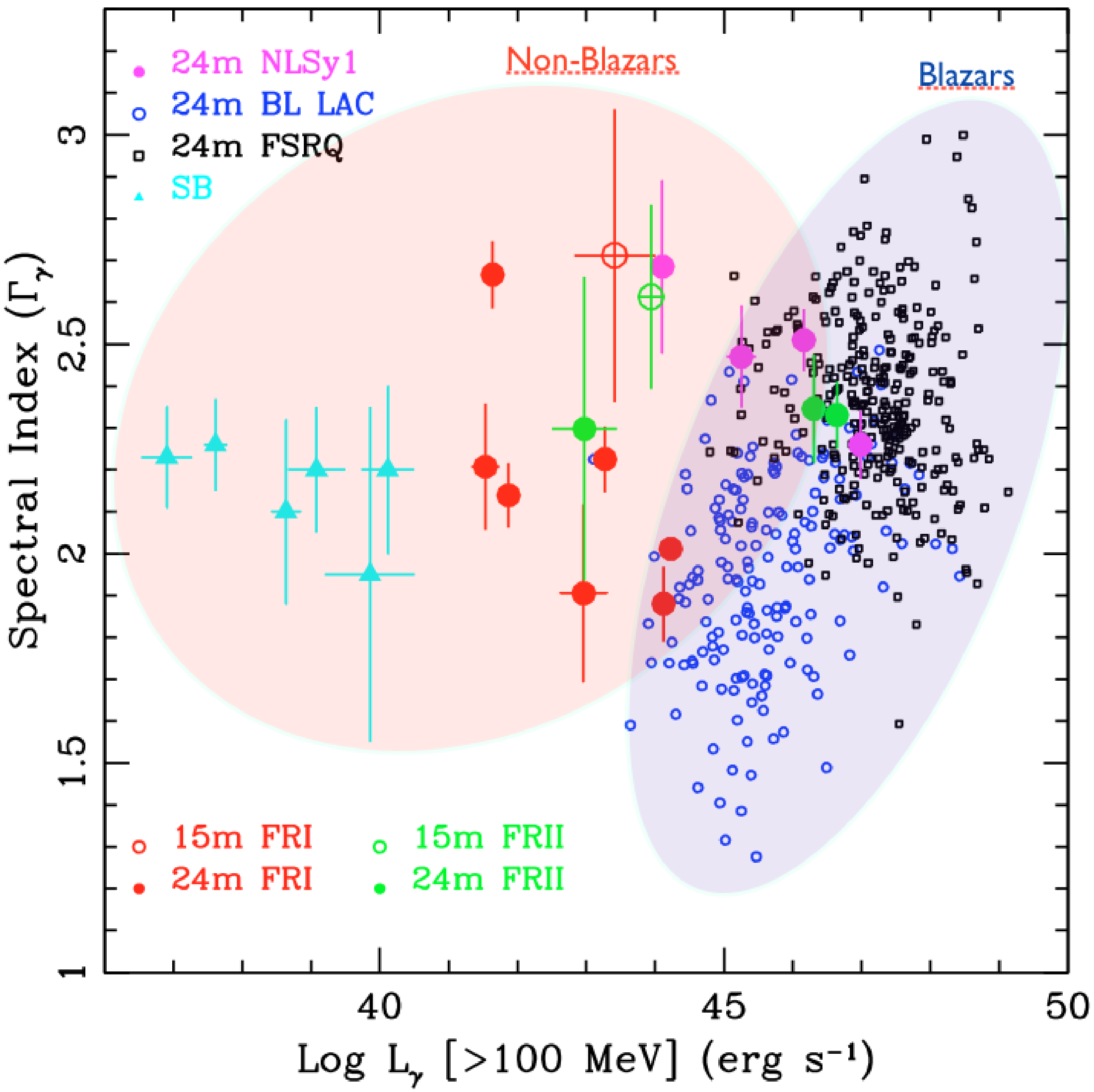
• **These gamma-ray NLS1s could be low mass (and possibly younger) version of the blazars in which the relativistic jet formation was triggered by a merger**



Thanks for your attention!!!

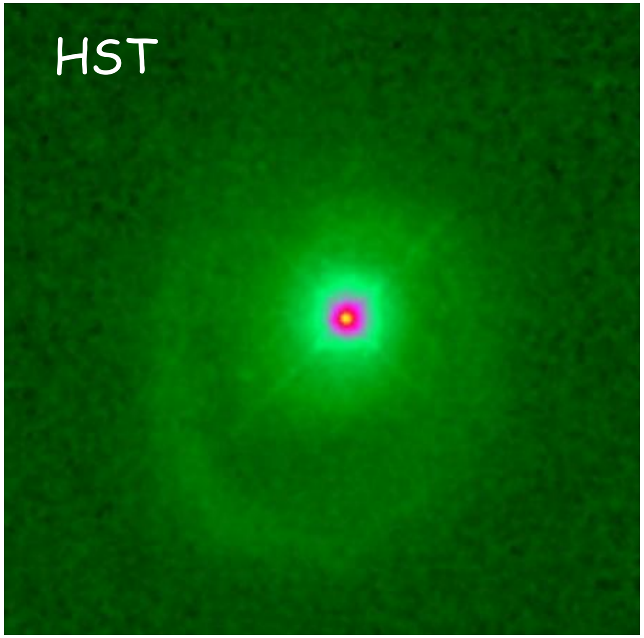
Extra Slides

The other NLS1 detected by Fermi-LAT



Grandi and Torresi 2012

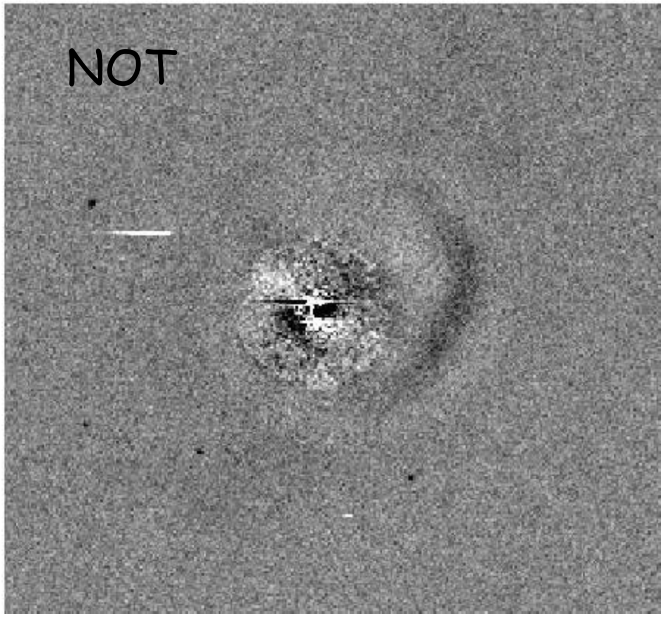
Host galaxy of 1H 0323+342



z = 0.061

Zhou et al. 2007: likely spiral morphology

Anton et al. 2008: circumnuclear region, residual of a merging galaxy?



No other HST observations of gamma-ray NLS1!

The development of relativistic jets in this object could be due to strong merger activity is not ruled out.

Host galaxy of gamma-ray NLS1s

• Unfortunately only very sparse observations of the host galaxy of the radio-loud NLS1s are available at this time

• The sample of objects studied by Deo et al. (2006) and Zhou et al. (2006) had $z < 0.03$ and $z < 0.1$, respectively, including both the radio-quiet and radio-loud objects

• The BH masses of radio-loud NLS1s are generally larger with respect to the entire sample of NLS1s: $(2\text{-}10)\times10^{7}$ solar masses (Komossa et al. 2006), even if still small when compared to radio-loud quasars

• The larger BH masses of radio-loud NLS1s could be related to the prolonged accretion episode that can spin-up the BHs

• **The small fraction of radio-loud NLS1s with respect to radio-quasars could be an indication that in the former the high accretion usually does not last sufficiently long to significantly spin-up the BHs (Sikora 2009)**

Radio-loudness and jet formation

• The mechanism at work for producing a relativistic jet is not clear, and the physical parameters the drive the jet formation is still under debate

• One fundamental parameter could be the BH mass, with only large masses allowing relativistic jet formation

• Sikora et al. (2007) suggested that AGN with M_BH > 10^8 solar masses have radio laoudness 3 order of magnitudes greater than the AGN with M_BH < 3×10^7 solar masses

• Another fundamental parameters should be the BH spin, with SMBHs in elliptical galaxies having much larger spins than SMBHs in spiral galaxies

• **The spiral galaxies are characterized by multiple accretion events with random orientation of angular momentum vectors and small increments of mass, while elliptical underwent at least one major merger with large matter accretion triggering an efficient spin up of the SMBH**